On the Formation of Plasma Complex Structures in Argon Glow Discharge

Georgeta Strat, S. Gurlui and M. Strat
"Al. I. Cuza" University of Iasi, Romania
*"Gh. Asachi" Tehnical University of Iasi, Romania

In this paper we show some of the phenomena which take place in the plasma complex structures formed in the transition region between two negative glows.

1. Introduction

The complex plasma structures which appear in glow discharges such as a plasma formation near an anode, the stratification of the positive column of a glow discharge, the free formation formed at the contact region between two negative glows and others, are striking examples of the self-organization of a strongly nonechilibrum systems.

At the beginning of the 1970^s interpretation of the moving striations (ionization waves) was based upon hydrodinamic fluid models. However, in the glow discharges (low pressures and small currents) where most theoretical and experimental studies applied, a nonlocal kinetic analysis of the plasma is required. In the glow discharges where inelastic collisions prevail in the electron energy balance, the instabilities that appear because of some resonance kinetic effects [1]

Other recent research concerning the origin of coherent space charge configurations formed in plasma underlined that the key processes related to self-organization are the symmetry breaking of both the excitation and ionization cross section functions together with their spatial separation [2].

In this paper we show that the same phenomena take place in the plasma complex structures formed in the transition region between two negative glows.

2. Experimental set-up and results

The experimental device is presented in Fig.1

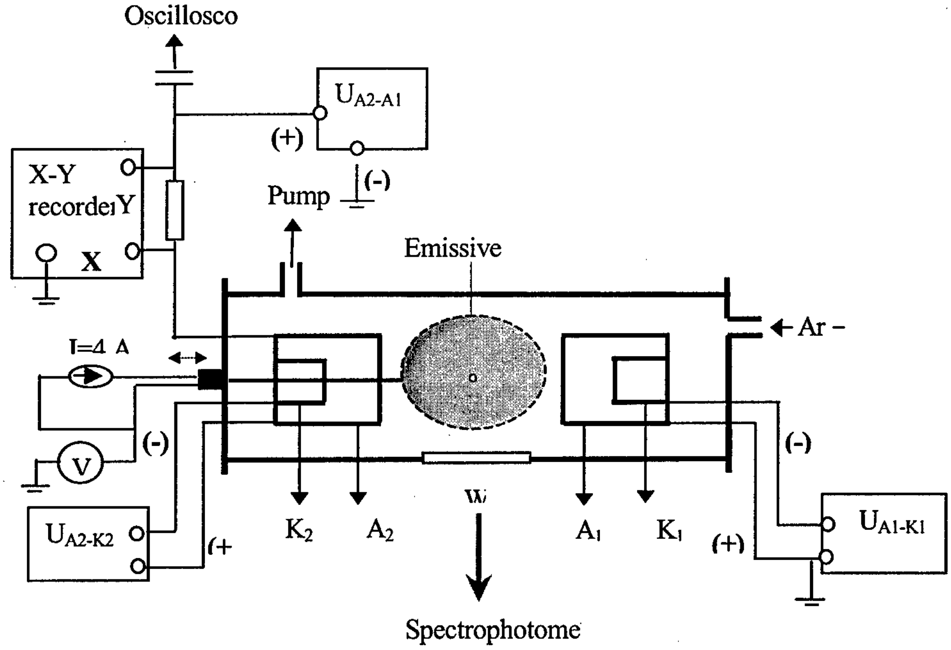

Figure 1 – The experimental set-up

A cylindrical stainless steel tube contains the following components: K_1, K_2-Al hole cathodes with 2.5 cm in diameter and 3.2 cm in lengths; A_1, A_2-cylindrical anodes with 7.0 cm in lengths and 4.0 cm in diameter, P– emissive probe (0.2 mm diameter Ta wire and 3 mm in lengths as a loop shape). Each anode was placed coaxial around the corresponding cathode and the probe, axially movable was passed through the K_2 axis. Axial and radial distributions of light intensity and corresponding optical spectra was obtained using a system of illumination of a entrance slit of a double mono-chromator with high spectral resolution (0,5 cm^{-1}). As it has been shown in many papers, the plasma double layers can be produced after a local acceleration of the electrons towards a pozitevely polarized electrode which is imersed in a plasma at a thermodynamic equilibrum and asymptotically stable. Under such conditions the initially present symmetry of all the functions that describe the physical system took into consideration (DL) is broken. This is the initial condition for the appearance of self-organization. From these functions the most important are the following : the excitation cross section, the ionization cross section, the ionization rate and the electron density. In these conditions, the sudden increase in different but adjacent regions of these functions determines the self-assemblage of an instability (for example a DL) whose stability is assured by electrostatic forces acting as long range correlation between the two space charges. The development of the axial instability is caused by the nonlocality of the electron distribution and ionization threshold, which results in the presence of phase shifts between the ionization rate and electron density [3].

The experimental device described above allows us to prove the role of the self organization processes in the apparition of plasma formations in the region between A_1 and A_2 anodes.

Thus, gradually increasing and decreasing the biased voltage on the anode A_2 (U_{12}) we obtained the I(V)-characteristic shown in Fig.2. The I(V) characteristic presents some non-liniarities which emphasize the existence of a multiplicity of states of the plasma formations created in the contact region between two negative glows by applying a positive voltage on the anode A_2.

In the voltage range, (V_1-V_2) (see Fig.2), the current, I_{12}, increase only a little (biased voltage ≈ 50 V). A further increase of the biased voltage (at V_3= 55 V) produces a sudden jump in the current (V_3-V_4).

The free floating plasma formations generated

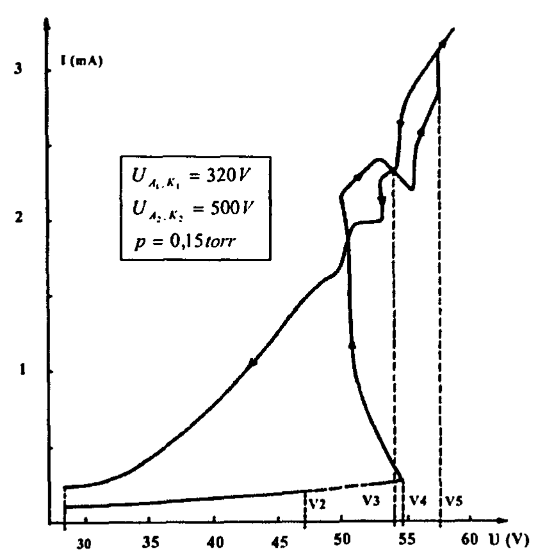

Fig. 2: The I(V)- characteristic in the case of existence of three plasma formations

this way are stable as long as the value of voltage V is between V_3 and V_5. When V is further increased the plasma formation becomes pulsatory.

For initiating the cascading self-organization processes it is necessary to bring the gaseous conductor in a bi-stable state obtained when V-value is between V_1 and V_3 [2]. In this voltage range, the current is situated in the low current branch of I(V) characteristic and in the contact region between the negative glows, it spontaneously initiates the self assemblage of the plasma formations accompanied by a sudden jump of the current. The experimental investigations proved the presence of the complex space charge configurations whose self-consistances are ensured by electrical double layers.

The study of the plasma formations, by means of electrical and spectral methods, shows that at the origin of the coherent space charge configurations formed in the plasma are the self-organization processes which begin when the symmetry breaking of both the excitation and ionizations cross section functions together with their spatial separation appears.

The development of the axial instability (DL) appears when there are phase shifts between the ionization rate and electron density.

In Fig.3 the axial profiles of the electron density and of the ion spectral line intensities, measured in the maximum, at different distances from de anode A_2 along one plasma formation are given.

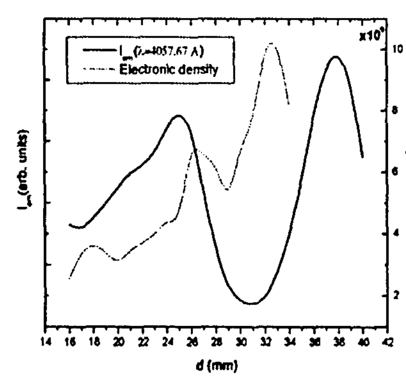

Fig. 3: The space shift between electron density and ionization rate

3. References

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